Reduced facilitatory influence of the supplementary motor complex on M1 in the presence of motor chunking

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Introduction

- Motor sequence learning (Willingham, 1999; Krakauer et al., 2019) and motor chunking (Verwey et al., 2002; Sakai et al., 2004) have been associated with the supplementary motor complex (SMC).
- However, studies that dissociate the sequential and chunking components to investigate their independent contributions to skill acquisition are limited.
- The key question is whether the SMC is engaged merely by the presence of sequential content in an action or by the need to organize rudimentary elements of an action through chunking.
- In this study, we used dual-coil paired-pulse transcranial magnetic stimulation (ppTMS) to measure changes in corticocortical excitability between SMC and the primary motor cortex (M1) following motor sequence training that includes either the sequential component and/or the chunking component.

Methods

- 69 right-handed undergraduate students participated in this study (mean age ± SD: 21.14 ± 2.87; 50 females).
- Individuals were randomly assigned to one of four conditions: (1) sequence (+) chunking (+), (2) sequence (+) chunking (-), (3) sequence (-) chunking (+), or (4) sequence (-) chunking (-) (see **Figure 1**).
- All participants experienced two separate administrations of ppTMS at SMC and M1 before and after the motor sequence training: (1) pre-training stimulation and (2) post-training stimulation (see **Figure 1**).
- **Targeting SMC:** 4 cm anterior to Cz in the international 10-20 system (Arai et al., 2012; Green et al., 2018; Rurak et al., 2021)
- **ppTMS coil orientation:** 45 (M1) and 270 (SMC) degrees to the midline of the brain (Arai et al., 2012; Rurak et al., 2021)
- **ppTMS intensity:** 110% (M1) and 140% (SMC) of the resting motor threshold
- **ppTMS interstimulus interval:** 7 ms (Rurak et al., 2021)

Results

- The findings of the present study confirmed a facilitatory influence of SMC on M1 in accordance with previous SMC-M1 ppTMS studies (Arai et al., 2011, 2012; Bevacqua et al., 2024; Green et al., 2018; Neige et al., 2023; Rurak et al., 2021) (see **Figure 2**).
- Additionally, our findings revealed that even in the absence of a motor sequence, the facilitatory influence of SMC on M1 was reduced if motor chunking occurred (see **Figures 2 and 3**).

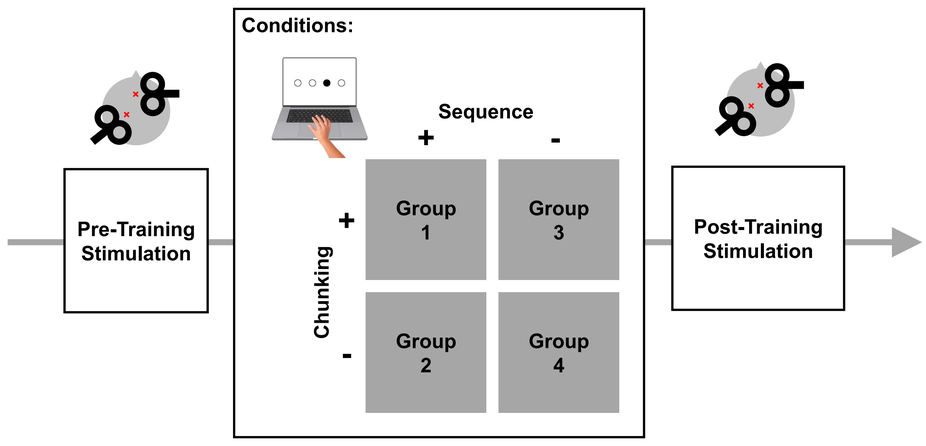

Figure 1. Experimental procedure.

1. Supplementary motor complex (SMC) exerts a facilitatory influence on M1.

2. Motor chunking reduced the facilitatory influence of SMC on M1, even without a motor sequence.

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Results (cont.)

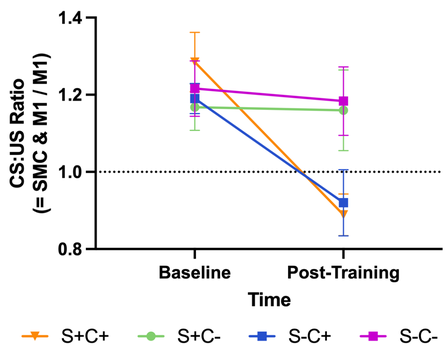

Figure 2. Conditioned stimulus (CS) to unconditioned stimulus (US) MEP ratio changes. Error bars represent standard errors.

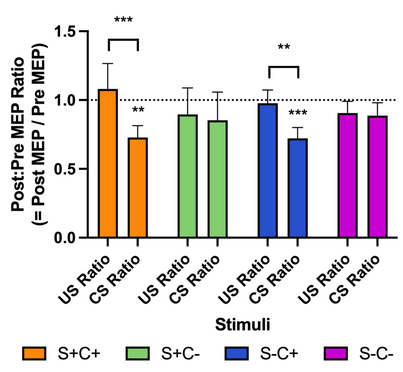

Figure 3. Post- to Pre-Training MEP ratio changes. Values less than 1 indicate decreased MEP ratios after the motor task. Error bars represent standard errors.

Discussion

- We speculate that these results imply that the use of the chunking strategy required repetitive inhibition of hand movements involving the cortico-basal ganglia-thalamo-cortical pathway, which includes inhibitory pathways (**Figure 4**), leading to a reduction in the facilitatory influence of the SMC on M1 (see **Figure 3**).

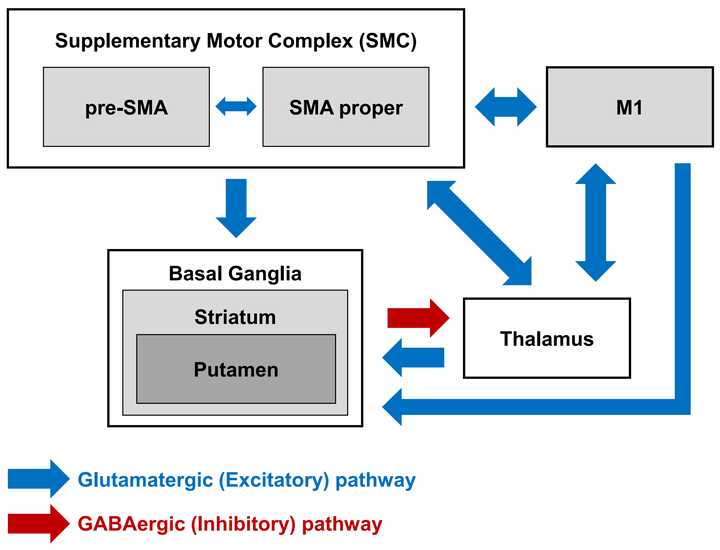

Figure 4. Pathways between SMC and M1. The blue arrows indicate the glutamatergic pathway (i.e., excitatory), and the red arrow indicates the GABAergic pathway (i.e., inhibitory).

Discussion (cont.)

- This explanation is congruent with data from neuroimaging studies (Wymbs et al., 2012) and studies using a stop-signal reaction time task that does not involve a sequential component (Wessel & Anderson, 2024).
- Future studies utilizing neuroimaging techniques are needed to verify the involvement of subcortical regions.

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